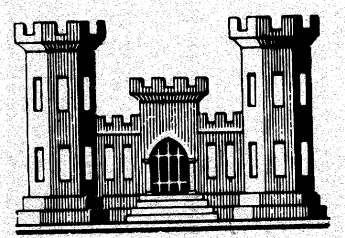
WATER RESOURCES INVESTIGATION

THREE RIVERS
LOCAL PROTECTION PROJECT

CHICOPEE, WARE and QUABOAG RIVERS
CONNECTICUT RIVER BASIN

SITUATION REPORT



Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

JULY 1976

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PALMER, MASSACHUSETTS

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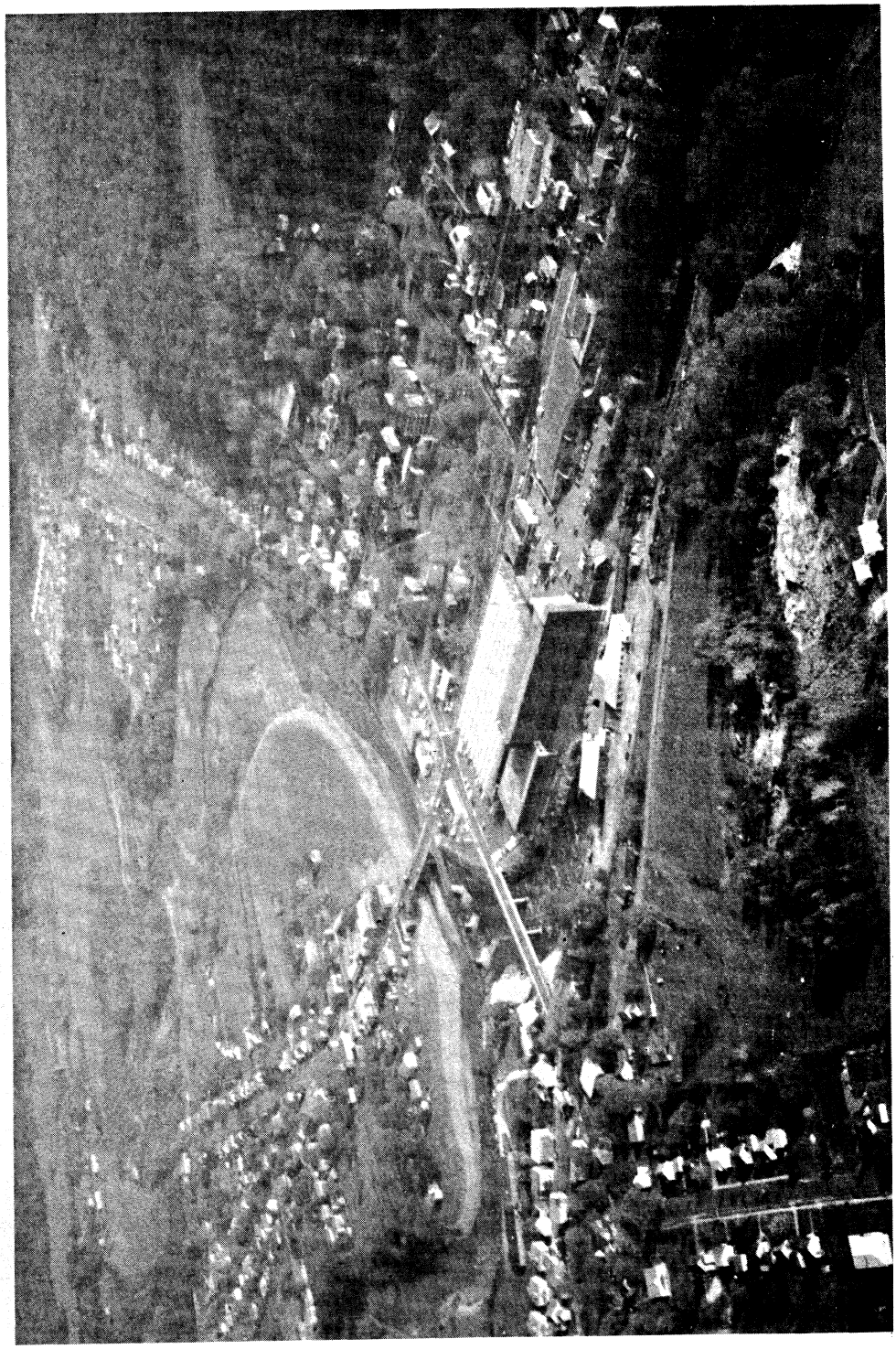

ThreeRivers Local Protection Project

Frontispiece

SYLLABUS

This situation report, although similar in part to an authorized study under Section 216 of the Flood Control Act of 1970, includes results of a review of the operational adequacy of the project and presents hydrologic and stability investigations to determine the advisability of further studies under the Section 216 Authority.

The report presents the results of our review of the completed Three Rivers Local Protection Project located on the Quaboag, Ware, and Chicopee Rivers in Palmer, Massachusetts. Because erosion problems have developed since the project became operational in 1966 the project was examined in light of current design criteria.

The stability analysis revealed that the existing stone sizes and layer thicknesses are in accord with that required by current design criteria except along the Chicopee River where a 400-foot section of the stone protection is deficient in layer thickness. This deficiency, however, is not considered critical since failure would not result in the loss of life or valuable property.

The hydrologic analysis revealed two minor problems within the project's limits and a chronic bank erosion problem upstream of the project on the Quaboag River. The minor problem areas are located along the Quaboag River in the vicinity of the Main Street bridge and consist of a depressed area in the stone protection and an area of chronic shoaling just downstream of the bridge. The chronic shoaling is minor and is being removed periodically by the Town of Palmer under their operation and maintenance program. The depressed area along the right bank of the Quaboag River resulted from the removal of an old building which abutted the stone protection. It is recommended that the Town of Palmer meet this problem by filling and riprapping to elevation 309 feet msl.

Since completion of the Three Rivers Project in 1966, there has been a continual history of channel and bank erosion along the Quaboag River in the reach immediately upstream of the project.

THREE RIVERS LOCAL PROTECTION PROJECT

CHICOPEE, WARE, AND QUABOAG RIVERS

PALMER, MASSACHUSETTS

CONNECTICUT RIVER BASIN

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Situation Report

THE STUDY AND REPORT

Purpose and Authority

There is a continuing need to assure that existing Corps projects are in accord with present day needs, that they are structurally sound, and that they have remained operationally adequate. This review of the operational adequacy of the completed Three Rivers Local Protection Project at Palmer, Massachusetts was initiated because of changed conditions and new design criteria since the project's completion in 1966. This situation report was accomplished to determine if a more extensive study and feasibility report under the authority of Section 216 of the 1970 Flood Control Act is warranted at this time.

Scope of Study

This is a report of survey scope. Unlike an authorized study under the Section 216 Authority, this report does not include investigations in all disciplines but rather focuses on the hydrologic and stability investigations and their conclusions as a basis for determining whether further studies are needed.

The items used in the technical review of this project consisted of as-built construction drawings, project reports, gaging station records and the information obtained from reconnaissance

investigations of the project site. Office studies consisted of updating the original hydrologic and stability analyses to determine how changes in the design criteria have affected the operational adequacy of the project.

COORDINATION WITH LOCAL INTERESTS

Coordination was limited to the local level since this report deals solely with the operational adequacy of the project and not with project reformulation.

On 23 July 1975 a field investigation and meeting with officials of the Town of Palmer, Massachusetts was held to inform the town of our on-going study and to determine if the town was aware of any problems which have developed as a result of the project. Several problems were sighted and these are discussed in subsequent paragraphs under the heading "Status of Existing Plans and Operations."

THE STUDY AREA

Project Description

The Three Rivers Local Flood Protection Project, a part of the Chicopee River flood protection plan authorized by Public Law 86-645, 86th Congress, adopted 11 July 1960, is located where the Ware and Quaboag Rivers join to form the Chicopee River in the Town of Palmer, Hampden County, in the south-central part of Massachusetts. The project extends from the site of the former New England Power Company dam on the Chicopee River upstream to the confluence of the Chicopee, Quaboag and Ware Rivers, continuing about 700 feet on the Ware River, and 1,500 feet on the Quaboag River. The project site lies in what was formerly the pool formed by the New England Power Company dam. The project was designed to reduce flood levels due to backwater from the New England Power Company dam and upstream restrictions which produced disastrous flooding levels in 1936, 1938, and 1955.

Initiated in 1964 and completed in 1966, the Three Rivers Project consisted of the complete removal of the New England Power Company dam to streambed. An improved channel was constructed upstream from the site of the dam, having a bottom width of 120 feet

at Station 0 + 00, converging uniformly to 80 feet at Station 12 + 00, to conform to physical limitations along the right bank imposed by the location of the Tampax Corporation building.

From Station 21 + 00 the bottom width increases uniformly to 140 feet at Station 24 + 00 and then to 200 feet at Station 27 + 00. It remains 200 feet wide to Station 28 + 00, just below the confluence of the Ware and Quaboag River. From this point the channel sides are altered to provide a smooth transition to the Ware and Quaboag Rivers. The minimum bottom width of the Ware River is 140 feet up to Station 37 + 49, the limit of the project on this stream. The Quaboag River also has a minimum bottom width of 140 feet to the limit of the project at Station 45 + 00.

The bottom of the channel was excavated to elevation 270.0 feet, msl at Station 0 + 00 and is level to Station 21 + 00. From this point the bottom rises to an elevation of 284.0 feet, msl at Station 26 + 00, with a slope of 0.028 feet per foot. The invert slope changes at Station 26 + 00 to 0.0064 feet per foot, and the channel rises to an elevation of 286.8 feet, msl at Station 30 + 35. The same slope was continued up the Quaboag River to meet the then existing streambed elevation of 296.2 feet, msl at Station 45 + 00. The bottom of the Ware River rises from an elevation of 286.8 feet, msl at Station 30 + 35 to the existing elevation of 293.9 feet msl at Station 37 + 50, with a slope of 0.010 feet per foot. A plan and a profile of the Three Rivers project can be found on Plates 1 and 2, and pertinent data on the project can be found in Table #1.

The channels in the project area are trapezoidal in shape except at locations of vertical concrete walls and rock cuts which occur on both the right and left banks of the Chicopee River between Stations 19 + 00 $\pm$ and 25 + 00$\pm$. A vertical wall was also built on the left bank of the Quaboag River between Station 31 + 50 and 32 + 60. Side slopes are 4 on 1 in rock and 1 on 1.5 in earth with a 5-foot berm between the top of the excavated rock and the toe of the earth slopes. For improved flow conditions, spoil was placed at the junction of the Quaboag and Ware Rivers below the Main Street bridge. In both cases the fill was placed on a 1 on 2.5 slope from the top edge of the excavated channel and protected with riprap. Fill was placed to an elevation of 309.0 feet, msl.

Two bridges were modified and one was replaced to increase channel capacity. The Bridge Street bridge, a stone arch bridge, was replaced with a steel bridge having three 80-foot spans providing three feet of freeboard between design water level and low chord. The Central Vermont Railroad bridge and the Main Street bridge were both lengthened with additional spans. The effect of these improvements was to reduce flood stages of a recurring August 1955 flood through Three Rivers by about 10 feet, while increasing velocities. Natural and modified profiles are shown on Plate 2.

Other Projects Within Chicopee River Basin

In addition to the Three Rivers Local Protection Project the Corps of Engineers has constructed six other flood control projects within the Chicopee River Basin. These are:

a. Barre Falls Reservoir on the Ware River in Barre, Massachusetts (D.A. = 55.0 square miles) completed in 1958.

b. Ware Local Protection Project on the Ware River and Muddy Brook in Ware, Massachusetts (1,125 feet of earth dikes and 12,000 feet of channel improvement) completed in 1960.

c. West Warren Local Protection on the Quaboag River in West Warren, Massachusetts (earth and rock fill dikes, concrete flood walls, channel improvement and reconstruction of an existing bridge) completed in 1963.

d. Conant Brook Reservoir on Conant Brook, a tributary to the Quaboag River in Monson, Massachusetts (D.A. = 7.8 square miles) completed in 1968.

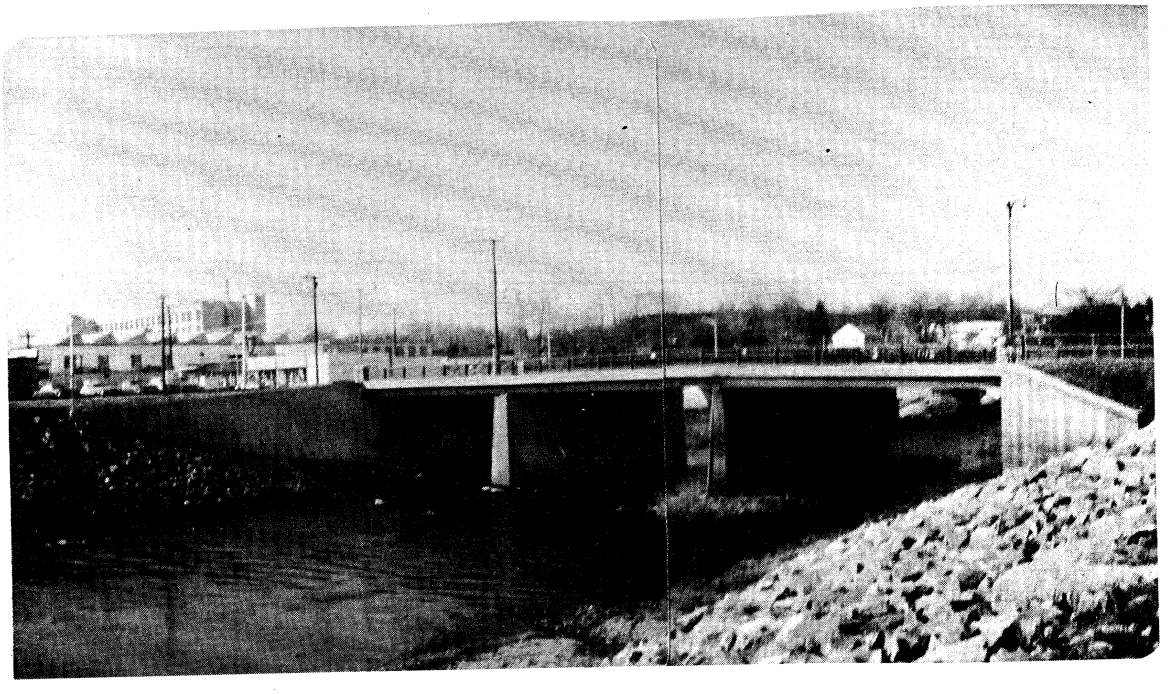
e. Chicopee Falls Local Protection Project on the Chicopee River in Chicopee Falls, Massachusetts (5,040 feet of concrete floodwalls and earth dikes, one pumping station and two gravity outlets) completed in 1965.

f. Chicopee Local Protection Project on the Chicopee and Connecticut Rivers in Chicopee, Massachusetts (25,700 feet of concrete floodwalls and earth dikes, six pumping stations and four stoplog structures) completed in 1941.

TABLE 1 : PERTINENT DATA
THREE RIVERS LOCAL PROTECTION PROJECT
PALMER, MASSACHUSETTS

Purpose:	Local Flood Protection		
Location:	At confluence of Quaboag, Ware and Chicopee Rivers in Town of Palmer, Hampden County, Massachusetts.		
Completed:	1966		
Improvements:	One dam removal, 5, 200 linear feet of channel improvement, one new bridge and two modified.		
Watershed Area at Site:	Quaboag River	210	square miles
	Ware River	435	square miles
	Chicopee River	645	square miles
Flood of Record:	Quaboag River	19, 700 cfs	Aug. 1955
	Ware River	24, 700 cfs	Sep. 1938
	Chicopee River	40, 000 cfs	Sep. 1938
Project Design Flood:	Quaboag River	20, 000 cfs	
	Ware River	32, 000 cfs	
	Chicopee River	50, 000 cfs	
Standard Project Flood:	Quaboag River	28, 200 cfs	
	Ware River	43, 800 cfs	
	Chicopee River	69, 000 cfs	

Site of Old New England Power Company Dam on the Chicopee River.



Looking downstream at Main Street Bridge along the Quaboag River just upstream of its confluence with the Ware River.

The location of the Three Rivers Local Protection Project and the other flood control projects in the Chicopee River Basin can be found on Plate 3.

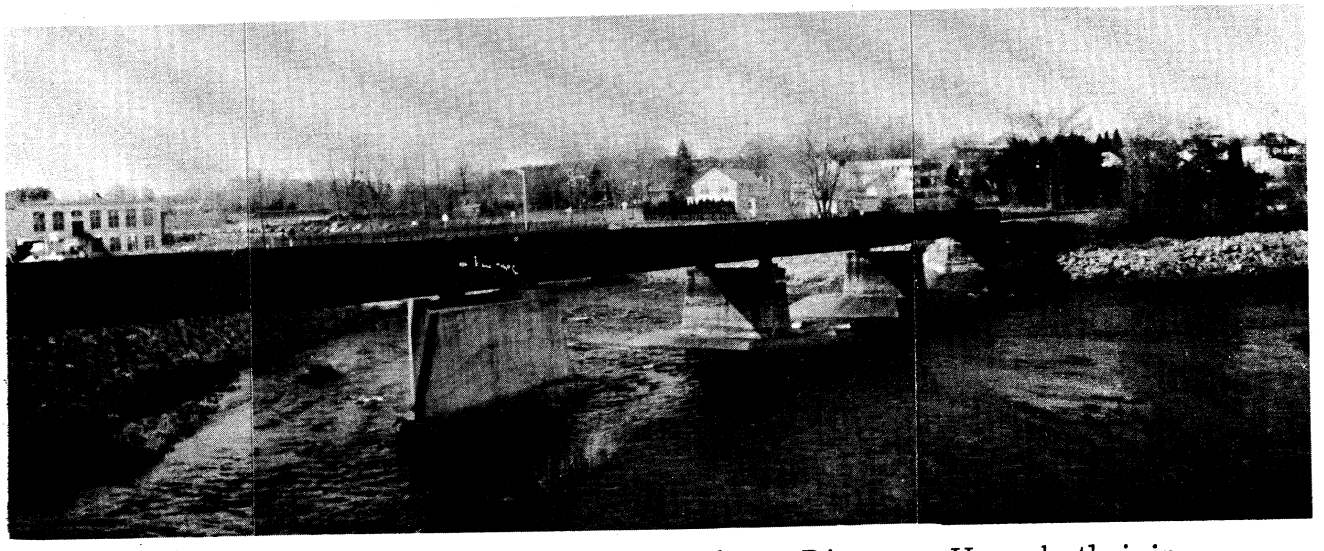
Environmental Setting

The project is located in the village of Three Rivers in the Town of Palmer, at the confluence of the Ware and Quaboag Rivers which join to form the Chicopee River. The project is capable of containing a streamflow of 50, 000 cfs, which eminates from its 645 square mile drainage basin. The drainage basin can be fairly equally divided among three tributary watersheds, namely: the Ware, Quaboag, and Swift Rivers with drainage areas of 218 square miles, 212 square miles and 215 square miles respectively.

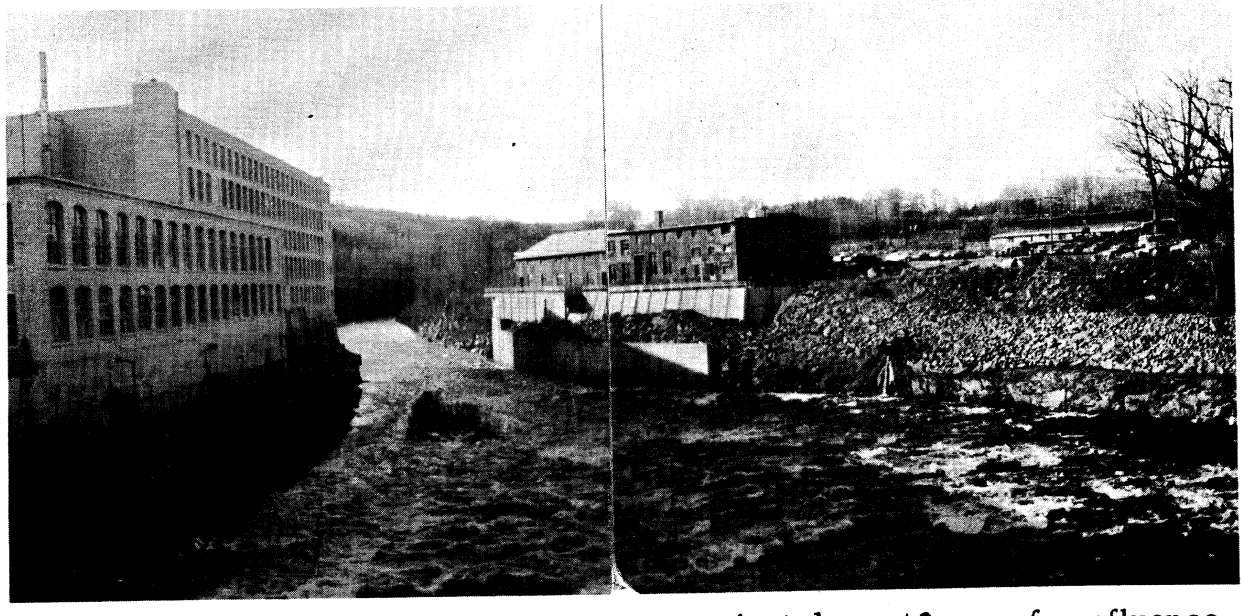
The relief of the basin varies from elevation 280 feet, mean sea level, at the project site, to elevation 1, 720 feet mean sea level at Wachusett Mountain in Princeton, Massachusetts in the northeast end of the East Branch Ware River watershed. The topography of the basin varies as the western portion is less rugged than the northern and northeastern sectors. In these rugged areas, the terrain is hilly and exhibits the surface characteristics and irregular drainage pattern typical of southern New England. Hills are prominent and valleys are steep and narrow. Most of the tributary streams are oriented in a north-south direction and flow almost due south. In the southern and western portions of the basin, mainly within the Quaboag River watershed, the valleys are broad with gentle slopes, Except in the dairy country of the Brookfields, and in Spencer and parts of Monson, the land in the Quaboag Basin is generally sandy and contains large boulders which provide soil characteristics undesireable for agriculture.

Although a very large percentage of the Chicopee River Basin has some sort of tree growth, very little is under heavy woodland cover. Gray birch, pitch pine and other shrub trees are the principal varieties found in the valley.

Within the watershed, are a number of natural and manmade lakes and ponds. The largest of the natural ponds is Quaboag Pond with a surface area of about 512 acres. Quabbin Reservoir, is the largest manmade lake in the State, boasting a surface area of approximately 39 square miles and controlling 188 square miles of the Swift River watershed. Covering 645 square miles at the project site, the basin encompasses some 23 cities and towns.



View of confluence of Ware and Quaboag Rivers. Here both join to form the Chicopee River.



Looking downstream at Chicopee River, just downstream of confluence of Ware and Quaboag Rivers.

Climatology

Located in south-central Massachusetts, the area offers a four season year with an average yearly temperature of around 49°F. Average monthly temperatures vary from 70°F in the summer to 25°F in the winter. The summer months of June to September show greatly varying daily temperatures ranging from highs upward to 100°F with cooler evenings falling into the 40's and 50's. The contrasting winter months of December to February range in temperature from below zero to the mid 30's.

Annual precipitation levels for the basin average approximately 44 inches. In general, the precipitation is evenly distributed throughout the year, although considerable variation occurs in individual months. Snowfall in the area averages 50 inches annually. In late February, snow cover reaches maximum depths with the water content in early spring often reaching about three to four inches. Contributing to these precipitation levels are the storms or "lows" that move in from the west or southwest. These storms are seldom severe. Storms of extreme severity which hit the area are the occasional coastal storms which migrate up the Atlantic Coast. Of tropical origin, these storms sometimes attain hurricane intensity. Two such storms occurred in this area in September 1938 and August 1955 each depositing an average of 12 inches of rain. As a result of these storms, record flows were recorded on the Ware, Swift and Chicopee Rivers in 1938, while record flows were recorded on the Quaboag River in 1955.

INVESTIGATIONS

General

Investigations were made in the areas of hydrology and foundations and materials. In addition, the general operation of the project was evaluated to determine if any significant problems have developed since the project's completion in 1966.

Status Of Existing Plans And Operations

Since completion of the Three Rivers Project, there has been a continual history of channel and bank erosion along the Quaboag River in the reach immediately upstream of the project. It is believed that this erosion was aggravated by the removal of the New England Power Company dam and improvement of the channel which drained the pool

and increased flow velocities on the Quaboag River. Erosion was first evidenced in August 1967. At that time, it was observed that erosion of the Central Vermont Railroad embankment on the left bank of the Quaboag was occurring and extended for a distance of approximately 200 feet opposite station 46 + 00. (All stationing referred to is that of the Corps stationing on the project). Erosion of the channel invert immediately upstream of the project was also noted. At this point, channel invert elevations had dropped an estimated four (4) to six (6) feet from those recorded in the Corps of Engineers survey of March 1962. It was assumed that the erosion resulted during the freshet of May 1967 which produced flows of 2, 000 ± cfs and channel velocities of 8 to 10 fps. It was concluded that the increased velocities scoured away the soft unstable material which had been deposited in the past. The erosion had occurred in the alignment of an old thalweg in the pond. No erosion of overburden material on the overbank areas was noted.

During the first week of February 1970, considerable rainfall caused the Quaboag River to overflow its banks at various locations upstream of the project resulting in lowland flooding. Several areas of bank erosion occurred immediately upstream of the project resulting in some storm drain lines being washed out or exposed.

Since 1970, there has been a continual problem with bank erosion at two locations on the Quaboag River just upstream of the project limit. Both are on the outside banks of sharp bends in the river. The first and most serious of the two is about 2, 000 feet upstream of the Main Street Bridge along the toe of a 25 to 30 foot slope located behind a single family dwelling at the end of Ford Street. The second location, about 500 feet upstream from the first and on the opposite bank is at the end of Bourne Street and is resulting in a loss of land but not endangering any structures.

Local remedial work on erosion problems at Three Rivers has been performed at various times by several agencies. The initial erosion of the railroad embankment, because of its occurrence shortly after completion of the Three Rivers Project, was dealt with jointly by the Corps of Engineers and the Central Vermont Railroad on a cost reimbursable basis. Work consisted of stone slope protection

for a distance of about 200 feet with a toe extending into the river. Subsequent inspections of this work indicate that no further erosion has taken place at this location and that the remedial work is performing well.

The erosion damage along the left bank of the Quaboag River caused by the flows of February 1970, including the damaged storm drains was repaired by the Town of Palmer.

In May 1973, the Town of Palmer requested assistance from the Corps of Engineers under Section 14 of the special continuing authorities programs and State officials to remedy the erosion taking place at the Ford Street site. No State or Federal aid was justified, therefore, action was subsequently taken by the town to relocate the channel away from the embankment at that location. Work consisted of bulldozing river gravel toward the eroding bank, filling in the area which was the river channel and relocating the channel to its former location.

The Commonwealth of Massachusetts recently let a contract for remedial work at the Bourne Street erosion site. Rock slope protection was placed along the outer bank of the river for a distance of approximately 400 feet following the existing bend in the river.

Another area of concern is located on the downstream side of the Main Street Bridge on the Quaboag River where shoaling has been a chronic problem. The shoaling, which is the result of the erosion problems upstream, does not have any significant detrimental effect on the project's operation and deposits are periodically removed by the Town's maintenance crew.

The right bank of the Quaboag River downstream of the Main Street bridge is protected to elevation 309 feet msl except at the site of an old building on Main Street. This building has burned and its remains removed resulting in a vacant depressed area about 30 feet wide. The elevation of the depression is approximately 300 feet msl, or about 9 feet below the adjoining bank and about 8 feet below design flood level.

Hydrology

a. Purpose.

The project was evaluated using current hydrologic criteria which have changed since completion of the project in 1966. This portion of the report contains sections on the hydrologic background of the project and project area and reports the results of the hydrologic evaluation of the project.

b. Discharge Records.

1. General.

The U. S. Geological Survey published records at eight stream gaging stations in the Chicopee River Basin. There are gaging stations on the Ware, Quaboag, and Chicopee Rivers all in the general vicinity of the project. Streamflow records at these three gaging stations are summarized in Table 2.

2. Runoff.

The mean annual runoff, as actually experienced at Indian Orchard for the 35 years of record, varies from 360 to 1,688 cfs with a mean of 803 cfs. Since 1940, flows from the Ware and Swift Rivers have been reduced by the operation of Quabbin Reservoir and the Coldbrook Diversion. Quabbin Reservoir, the principal water supply for Metropolitan Boston, is located on the Swift River, a tributary to the Ware River, approximately 21 miles upstream from Indian Orchard. It has a drainage area of 186 square miles representing over 86 percent of the total Swift River watershed. Coldbrook Diversion is located on the Ware River approximately 4 miles downstream from Barre Falls Dam, where flows are diverted by tunnel to either Quabbin or Wachusett Reservoirs. There are 97 square miles of drainage area above the diversion. Table 3 is a summary of the maximum, minimum, and mean monthly flows on the Chicopee River at Indian Orchard since the construction of Quabbin Reservoir.

c. Historic Floods.

1. General.

Four floods of major proportions have occurred in the Chicopee basin. Pertinent data on these floods at the three key gaging stations on the Ware, Quaboag and Chicopee Rivers are listed in Table 4. Since completion of the Three Rivers Project, only moderate freshets have been experienced. These occurring in March 1968, February 1970 and December 1973, with recorded flows on the Chicopee River at Indian Orchard of 6, 500, 5, 980, and 5, 630 cfs, respectively.

2. 1936 Floods.

The first of the two March 1936 Floods was caused by a combination of rainfall and snowmelt. The second flood, which was the more destructive, involved only minor amounts of snowmelt but had considerably more rainfall. Also, the second flood followed the first so closely as to occur with nearly saturated ground conditions and nearly bank full channels. The peak 1936 discharge resulted from about 4. 5 inches of rainfall.

3. 1938 Flood.

The September 1938 flood produced the greatest flood of record along the Ware, Swift and Chicopee Rivers. Natural storage areas in the basin were filled by the time of the most intense rainfall, so the time sequence of this hurricane storm was conducive to high peak discharges. The 1938 flood was produced by rainfall amounts ranging from 10. 5 to 13. 0 inches over the Chicopee basin.

4. 1955 Flood.

The August 1955 flood produced by far the greatest peak flows of record along the Quaboag River. On the Ware and Chicopee Rivers the 1955 flood was second only to that of September 1938.

d. Flood Frequencies.

During the design of the Three Rivers Project, discharge frequencies were developed at four gaging station sites in the basin. The developed frequency curves are shown on Plate 5. In addition, a frequency curve for flows at Indian Orchard, as modified by Barre Falls and Conant Brook Reservoirs, is also shown. A review of discharge frequencies, using updated peak flow data, indicated no significant change in flood frequencies. If anything, a slight decrease from previously developed frequencies was indicated.

e. Project Design Flood.

During the design of the Three Rivers Project, a standard project flood was developed for the Chicopee River basin using the synthetic rainfall from Civil Works Bulletin 52-8 and unit hydrographs developed from floods of record. The derivation of the standard project flood was described in Appendix B of the Interim Report on Review of Survey, Chicopee River basin, dated 8 September 1959. The resulting peak discharge at Indian Orchard is 77, 800 cfs, or about 72 percent greater than the record flood of 45, 200 cfs experienced in September 1938. Designing for the SPF discharge of 69, 000 cfs at Three Rivers was found to be impractical and economically unjustified. The adopted design flood for the Chicopee River portion of the project was set at 50, 000 cfs which is about 25 percent greater than the maximum flood of record, as modified by the Barre Falls and Conant Brook Reservoirs.

f. Flood Profiles

In current studies, flood profiles were reanalyzed using the HEC-2 "Water Surface Profile" computer program. Profiles were developed assuming a Manning's "n" of 0. 035. Expansion and contraction coefficients were 0. 3 and 0. 1 respectively.

Backwater computations were made for both as-built and present day conditions, the principal difference in the two conditions being some lowering of the river invert on the Quaboag River due to erosion. Present day cross-sections were estimated by assuming a straight line invert from downstream bedrock control to recent point invert elevations on the Quaboag River, as established by Commonwealth of Massachusetts surveys. Flood and channel invert profiles are shown on Plate 2.

g. Riprap Analysis.

Using current tractive force criteria for the sizing of riprap, the resulting minimum D_{50}'s were computed at selected stations throughout the length of the project. The results of this analysis are listed in Table 5. This hydraulic analysis and resulting D_{50} information serves as the basis for further investigation of existing riprap adequacy.

It is noted that in those areas where the computed D_{50} is relatively high (Station 15 + 00 and 19 + 00) the channel is in bedrock and the areas are downstream of any buildings. The buildings bordering the Chicopee River immediately upstream of these stations are also founded on bedrock. Riprap placed along this high tractive force reach serves mainly to maintain channel alignment and to protect areas of shallow overburden. Riprap in this reach is not considered vital to project integrity.

TABLE 2

STREAMFLOW RECORDS - CHICOPEE RIVER BASIN

Location of Gaging Station	Drainage Area (sq. mile)	Period of Record	Mean(5) (cfs)	Maximum (1)	Minimum (1) (cfs)
Ware River at Gibbs Crossing	199	1912-1974	317	22,700 (2) 4,000 (4)	6.0
Quaboag River at West Brimfield	151	1909-1974	240	12,800 (3)	6.6
Chicopee River at Indian Orchard	688	1939-1974	1,080 803 (6)	45,200 (2)	16.0

(1) Instantaneous Discharge.
(2) September 1938.
(3) August 1955
(4) Since completion of Barre Falls Dam 1958.
(5) Adjusted for diversion or storage.
(6) Actual experienced flows at Indian Orchard.

TABLE 3

MONTHLY RUNOFF - CHICOPEE RIVER AT INDIAN ORCHARD MASSACHUSETTS
(in cfs)

D. A. = 688 Square Miles
October 1939 - September 1974

MONTH	MEAN	MAXIMUM	MINIMUM
January	805	1, 733	308
February	908	1, 880	394
March	1, 402	2, 494	646
April	1, 688	3, 471	824
May	1, 141	2, 324	527
June	765	2, 016	345
July	467	1, 177	217
August	436	2, 489	166
September	360	1, 211	159
October	375	1, 447	133
November	659	2, 199	252
December	778	1, 648	356
Annual	803	2, 480	320

NOTES: Flows at Indian Orchard are affected by diversion from the basin for Boston water supply via Quabbin Reservoir and the Coldbrook intake and do not reflect the true runoff from the drainage area of 688 sq. miles.

TABLE 4
MAJOR FLOODS

Flood	Ware River at Gibbs Crossing (DA = 199 sq. mi)		Quaboag River at West Brimfield (DA = 151 sq. mi.)		Chicopee River at Indian Orchard (DA =688 sq. mi.)	
	Average Rainfall (inches)	Peak Dis. Observed (cfs)	Average Rainfall (inches)	Peak Dis. Observed (cfs)	Average Rainfall (inches)	Peak Dis. Observed (cfs)
12 March 1936	2	5, 210	2	2, 040	2	14, 200*
19 March 1936	4. 5	11, 200	5	3, 620	4	20, 400*
September 1938	13. 0	22, 700	11. 5	8, 470	10. 5	45, 200*
August 1955	8	12, 200	15	12, 800	13	40, 500

* Chicopee River at Bircham Bend.

TABLE 5

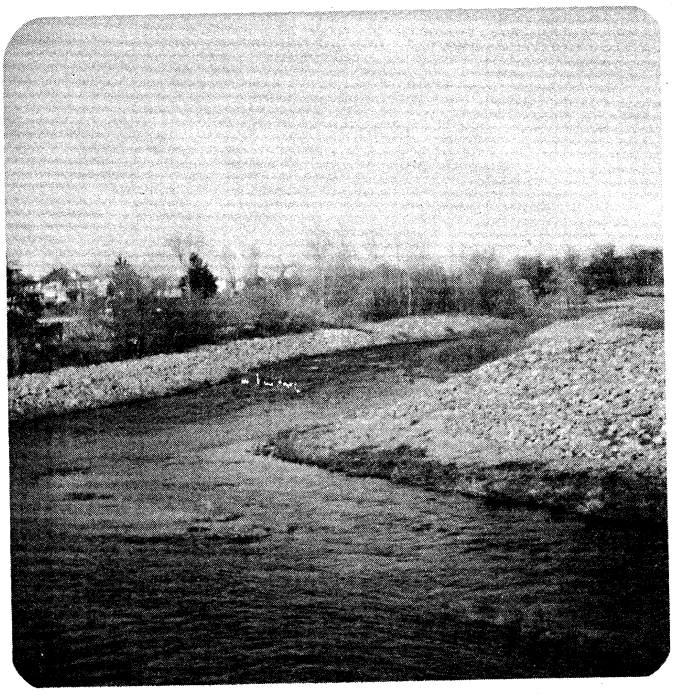
HYDRAULIC ANALYSIS FOR RIP RAP DESIGN

Station	River	Design Flood (1)					Moderate Flood (2)				
		Y (ft.)	Vch (f. P. S.)	Slope EG line (%)	Side Slope	D_{50} (min) (ft) (3)	Y (ft)	Vch (f. P. S.)	Slope EG line (%)	Side Slope	D_{50} (min) (ft)
15+00	Chicopee	28. 01	19. 59	0. 33	1 on 1. 5	2. 250	14. 90	12. 02	0. 30	1 on 1. 5	1. 200
19+00	Chicopee	29. 95	18. 50	0. 31	1 on 1. 5	2. 275	16. 38	10. 82	0. 23	1 on 1. 5	0. 875
24+00	Chicopee	26. 29	11. 61	0. 11	1 on 1. 5	0. 700	9. 39	10. 77	0. 36	1 on 1. 5	0. 900
25+00	Chicopee	23. 72	11. 35	0. 11	1 on 1. 5	0. 650	6. 37	13, 99	0. 96	1 on 1. 5	1. 450
26+86	Chicopee	19. 34	13. 90	0. 31	1 on 1. 5	1. 500	7. 11	11. 94	0. 70	1 on 1. 5	1. 450
27+34	Chicopee	20. 19	13. 03	0. 25	1 on 1. 5	1. 200	7. 48	10. 95	0. 55	1 on 1. 5	1. 000
30+00	Chicopee	20. 46	9. 06	0. 16	1 on 1. 5	0. 825	7. 91	7. 92	0. 33	1 on 1. 5	0. 650
33+73	Quaboag	19. 00	5. 80	0. 05	1 on 2. 5	0. 175	6. 75	6. 54	0. 17	1 on 2. 5	0. 325

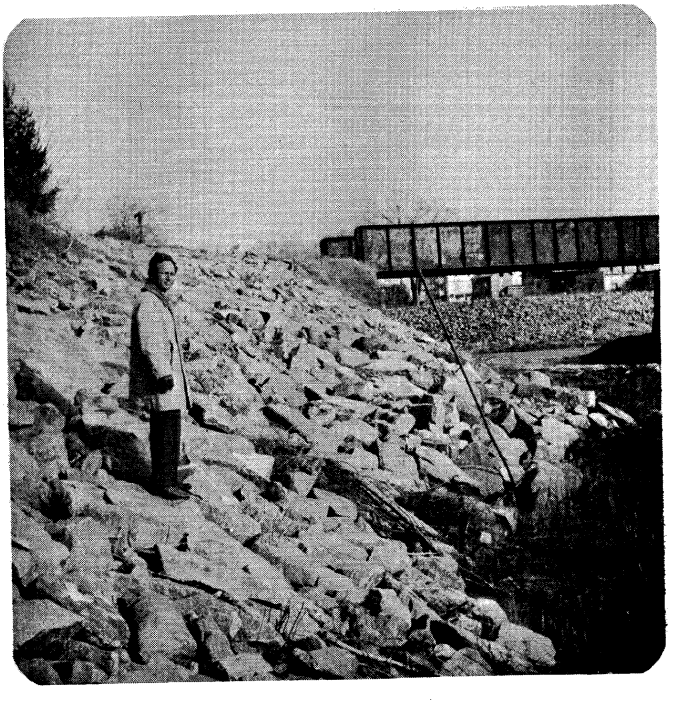
(1) Q = 50, 000 C. F. S. - Chicopee River, Q = 20, 000 C. F. S. Quaboag River

(2) Q = 15, 000 C. F. S. - Chicopee River, Q = 7, 500 C. F. S. Quaboag River

(3) D_{50} (min) is obtained from chart developed for Derby Local Protection Project, based on criteria for graded stone rip-rap channel protection O. C. E. draft report April 1966.



View of Stone Protection along Ware River just upstream of confluence with Quaboag River.



Stone Protection along Chicopee River just downstream of the confluence of the Ware and Quaboag Rivers.

Foundations and Materials

All embankments, filter layers and revetments were reanalyzed using current criteria to determine whether the project features have remained adequate. The results of the reanalysis are as follows:

a. Embankments.

The embankments on this project are less than 15 feet in height and were constructed to retain spoil material. They have adequate layers of stone protection and are considered to satisfy current criteria in their design. Inspection (December 1975) shows no sign of unsatisfactory performance.

b. Filter Layers.

The filter design procedure and criteria used for the gravel bedding layers are essentially the same as those in current use. Current criteria are satisfied.

c. Revetments.

1. The stability studies and physical characteristics of stone protection materials for design of the revetments for Three Rivers Local Protection, as presented in the General Design Memorandum, and project plans and specifications, have been reviewed in light of current practices and criteria. A field trip was made to the site to inspect the revetment and to measure and evaluate stone sizes. This review included the determination of shear forces created by channel flow and the ability of the revetment to withstand these forces.

2. Design criteria for stone revetments have changed significantly since this project was designed in 1963. The existing revetments were, therefore, evaluated in the light of current criteria. It was found that for the greater part of the project (upstream of the Bridge Street Bridge), the revetment satisfies current criteria. Downstream of the bridge the revetment is deficient in layer thicknesses according to current criteria. Modification of this portion of the revetment is not recommended; however, since its failure would not endanger life or cause extensive property damage.

3. The revetments are in good condition and show no sign of damage from erosion or weathering. They have been in place for twelve (12) years and exposed to flows of up to 7,000 cfs as compared to the design flood flow of 50,000 cfs.

4. Summary: As-built data for the revetments and current design criteria requirements are tabulated below:

Reach	In-Place	Required by Current Criteria--
Sta. 1+00 to 4+00	Max. Stone Size: 2000 lbs. Layer Thickness: 24 in.	Max. Stone Size: 1900-4600 Layer Thickness: 48 in.
Sta. 15+00 to 27+00 Bridge Street	Max. Stone Size: 2000 lbs. Layer Thickness: 24 in.	Max. Stone Size: 600-150 lbs. Layer Thickness: 30 in.
Upstream Sta. 27+00	Max. Stone Size: 2000lbs. Layer Thickness: 24 in.	Max. Stone Size: 90-750 lbs. Layer Thickness: 12-24 in.

Alternative Plans of Action Considered.

The operational problems discussed in the section entitled "Status of Existing Plans and Operations" were directly addressed during this review. The erosion on the Quaboag River at Three Rivers has been a long and continuing problem which in all probability was aggravated by the construction of the Three Rivers Local Protection Project and the removal of the New England Power Company Dam. From a hydrologic point of view, action on the matter could take any of three forms:

a. Minimal Plan of Action.

The minimal plan of action would be to do nothing in hopes that the channel has approached a new near stable condition. However, if erosion continues, it may be beneficial to acquire a complete set of base line surveys from the upper end of the project to the Massachusetts Turnpike overpass. Such surveys would be invaluable in monitoring future rate and magnitude of erosion. In addition, a pre-arranged plan could be developed whereby emergency stabilization work could be undertaken under short notice if the need should suddenly arise.

b. Moderate Plan of Action.

This intermediate plan would consist of completing the rip rapping of outer banks at all bends from the upstream end of the project on the Quaboag River continuing upstream to the Palmer Street Bridge. Included in this plan would be the inclusion of at least two channel stabilizers which would serve to minimize further erosion of the existing channel invert. Rip rap sizing for such a plan would require a D_{50} size in the order of 1.0 feet, capable of withstanding a tractive force of 4.1 pounds per square feet based on an assumed unit weight of rock of 165 pounds per cubic foot.

c. Major Action Plan.

A major action plan would in effect be the extension of the Three Rivers Project, 2,500 feet up the Quaboag River. Such a plan would provide a 125-foot wide trapezoidal channel with 1:2.5 rip rapped side slopes. Overbank areas should be preserved as flood plains but made available for recreation and public access to the improved river channel. This major plan would also contain a minimum of two channel stabilizers to minimize further degradation of the channel invert. Rip rap sizing for this plan would require a D_{50} size in order of 0.5 feet, capable of withstanding a tractive force of 2.10 pounds per square foot.

A typical cross section of this proposed channel and of a channel stabilizer is contained on Plates 7 and 8. In addition to addressing the erosion problem, the depressed area along the right bank of the Quaboag River downstream of the Main Street Bridge should be filled and riprapped to elevation 309 feet msl. The shoaling which has occurred in the area of the Main Street Bridge is chronic but minor and should be removed periodically.

SUMMARY

Under the Section 216 authority completed projects must be periodically reviewed to insure that they continue to function properly as physical conditions, design criteria and local needs and desires change. Since there are numerous local protection projects to be reviewed, preliminary reviews of the projects which focus on existing operational problems are being made to determine the severity and urgency of the problems.

Eroded Bank upstream of project limits on the Quaboag River near Bourne Street. This area has since been repaired by the State of Massachusetts.

Site of Ford Street erosion problem which was corrected by the Town of Palmer. The gravel area in foreground was placed there to shift course of Quaboag River away from house on hill.

This review of the Three Rivers Local Protection Project in Palmer, Massachusetts consisted of hydrologic and stability investigations. The results of these investigations are as follows:

- A determination of minimum rock sizes and layer thicknesses revealed that based on the changes in design criteria since the project was completed in 1966, all areas meet the requirements except downstream of the Bridge Street bridge where the layer thickness is slightly deficient for a distance of 400 feet.

- Two minor problems along the Quaboag River in the vicinity of the Main Street bridge were noted. The first is located along the right bank and consists of a low area in the stone protection. The other problem is a chronic shoaling problem located just downstream of the bridge.

- Since completion of the Three Rivers Project, there has been a continual history of channel and bank erosion along the Quaboag River in the reach immediately upstream of the project. The areas which have been eroded (Bourne Street, Ford Street and Central Vermont Railroad embankment) prior to the removal of the New England Power Company Dam were part of the dam's reservoir area. Removal of the dam has increased velocities which have been continually eroding away the silty bottom material.

The three principal problem areas have been corrected, the railroad embankment, by the Corps; the Ford Street problem, by the Town of Palmer; and the Bourne Street problem, by the State of Massachusetts. Although these areas of concern have been corrected, it is unknown whether the erosion will start at another location. Two structural and a non-structural method of dealing with this problem were considered as follows:

a. The minimal plan of action would not include any channel realignment or additional bank stabilization in this reach. However, the establishment of baseline surveys from the upstream limit of the project to the Massachusetts Turnpike overpass would be a valuable monitoring device.

b. The moderate plan of action would consist of completely rip rapping all outer banks at bends from the upstream end of the project to the Palmer Street Bridge. This plan would also include two channel stabilizers which would serve to minimize further erosion of the existing channel invert.

c. The major plan of action would be to extend the Three Rivers Project approximately 2, 500 feet up the Quaboag River. The proposed channel would be trapezoidal in shape with a 125 foot wide bottom and 1:2. 5 rip rapped side slopes. The addition of two channel stabilizers would also be included in this plan.

CONCLUSIONS.

Findings conclude that:

• The present operations and flood regulations of the project are satisfactory.

• There is no urgent need to modify the slightly deficient layer of stone protection located downstream of the Bridge Street bridge.

• The depressed area in the stone protection along the right bank of the Quaboag River should be filled and rip rapped to elevation 309 ft. msl. This repair is a local responsibility and should be done by the Town of Palmer under their Operation and Maintenance Program.

• The shoaling problem at the Main Street Bridge is minor but chronic and should be removed periodically by the Town of Palmer.

• Since the principal erosion areas upstream of the project have been corrected, no further channel or bank stabilization measures should be taken at this time. Baseline surveys from the project's upstream limit to the Massachusetts Turnpike overpass should be obtained in order to help monitor this stretch of the Quaboag River and will be given further consideration under the Operation and Maintenance Program, Periodic Inspection and Continuing Evaluation of Completed Civil Works Programs.

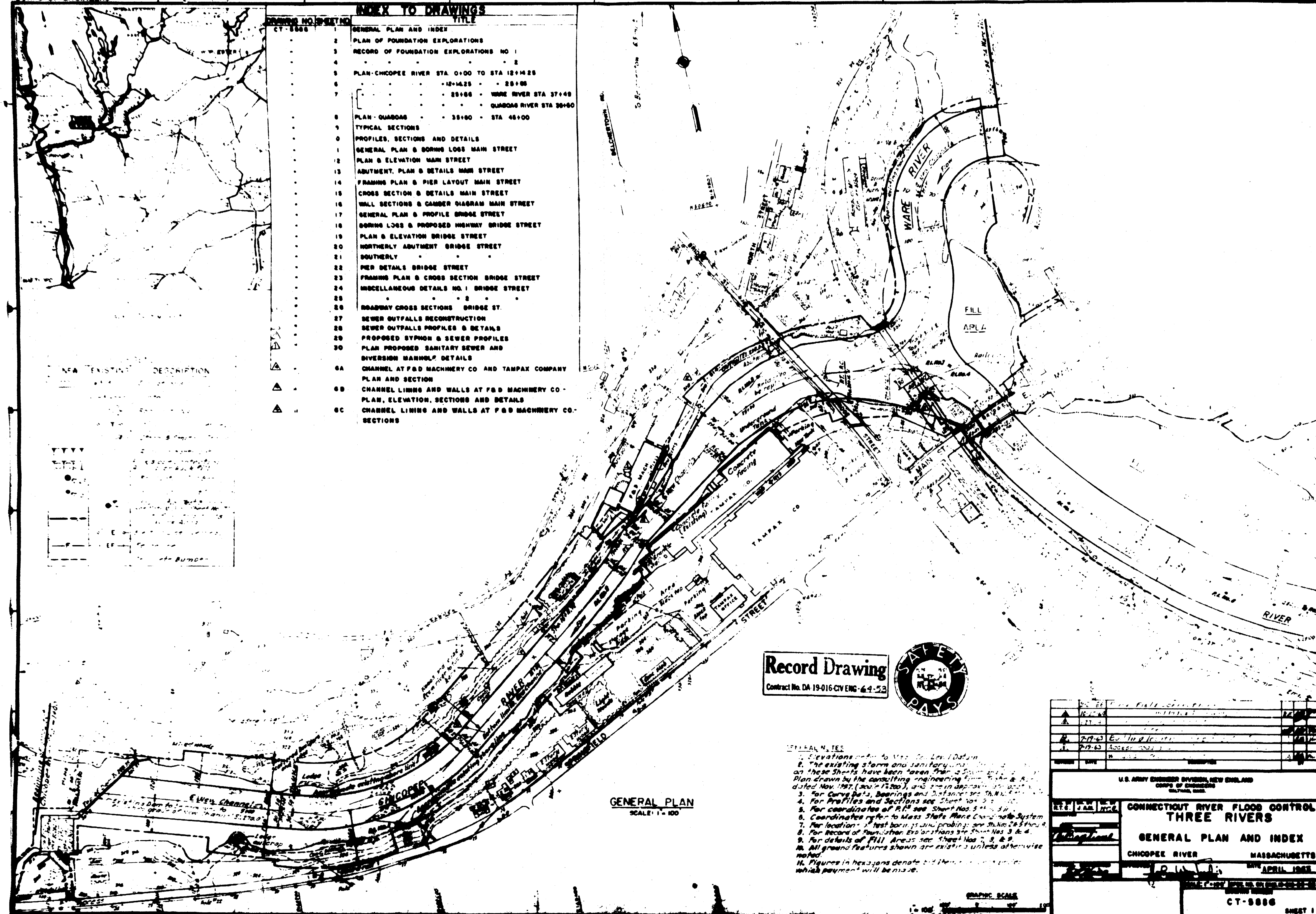
• Although the erosion problems are upstream of the actual project, future periodic inspections of the project by Operations Division should include a report on this reach of the river.

RECOMMENDATIONS

Based on this situation report, no further detailed studies under the Section 216 Authority of the 1970 Flood Control Act are recommended at this time.

JOHN H. MASON
Colonel, Corps of Engineers
Division Engineer

CORPS OF ENGINEERS — U. S. ARMY



INDEX TO DRAWINGS

DRAWING NO.	SHEET NO.	TITLE
CT-5886	1	GENERAL PLAN AND INDEX
"	2	PLAN OF FOUNDATION EXPLORATIONS
"	3	RECORD OF FOUNDATION EXPLORATIONS NO 1
"	4	" " " " " 2
"	5	PLAN-CHICOPEE RIVER STA. 0+00 TO STA 12+14.25
"	6	" " " " 12+14.25 " " 25+66
"	7	" " " " 25+66 " WARE RIVER STA 37+49 / " " " " " QUABOAG RIVER STA 38+60
"	8	PLAN - QUABOAG " " 38+60 " STA 46+00
"	9	TYPICAL SECTIONS
"	10	PROFILES, SECTIONS AND DETAILS
"	11	GENERAL PLAN & BORING LOGS MAIN STREET
"	12	PLAN & ELEVATION MAIN STREET
"	13	ABUTMENT, PLAN & DETAILS MAIN STREET
"	14	FRAMING PLAN & PIER LAYOUT MAIN STREET
"	15	CROSS SECTION & DETAILS MAIN STREET
"	16	WALL SECTIONS & CAMBER DIAGRAM MAIN STREET
"	17	GENERAL PLAN & PROFILE BRIDGE STREET
"	18	BORING LOGS & PROPOSED HIGHWAY BRIDGE STREET
"	19	PLAN & ELEVATION BRIDGE STREET
"	20	NORTHERLY ABUTMENT BRIDGE STREET
"	21	SOUTHERLY " " "
"	22	PIER DETAILS BRIDGE STREET
"	23	FRAMING PLAN & CROSS SECTION BRIDGE STREET
"	24	MISCELLANEOUS DETAILS NO. 1 BRIDGE STREET
"	25	" " " 2 " "
"	26	ROADWAY CROSS SECTIONS BRIDGE ST.
"	27	SEWER OUTFALLS RECONSTRUCTION
"	28	SEWER OUTFALLS PROFILES & DETAILS
"	29	PROPOSED SYPHON & SEWER PROFILES
"	30	PLAN PROPOSED SANITARY SEWER AND DIVERSION MANHOLE DETAILS
"	6A	CHANNEL AT F&D MACHINERY CO AND TAMPAX COMPANY PLAN AND SECTION
"	6B	CHANNEL LINING AND WALLS AT F&D MACHINERY CO - PLAN, ELEVATION, SECTIONS AND DETAILS
"	6C	CHANNEL LINING AND WALLS AT F&D MACHINERY CO.- SECTIONS

GENERAL PLAN
SCALE: 1" = 100'

GENERAL NOTES

1. Elevations refer to Mean Sea Level Datum
2. The existing storm and sanitary [illegible] on these Sheets have been taken from a [illegible] Plan drawn by the consulting engineering firm [illegible] dated Nov. 1957 (scale 1"=200'), and are in approximate [illegible].
3. For Curve Data, Bearings and Distances see Sh. No. [illegible]
4. For Profiles and Sections see Sheet Nos. [illegible]
5. For coordinates of P.I.'s see Sheet Nos. 5 [illegible]
6. Coordinates refer to Mass State Plane Coordinate System
7. For locations of test borings and probings see Sh. Nos. 2 & 5 thru 8.
8. For Record of Foundation Explorations see Sheet Nos 3 & 4.
9. For details of Fill Areas see Sheet Nos 7, 8, & 9.
10. All ground features shown are existing unless otherwise noted.
11. Figures in hexagons denote bid item [illegible] under which payment will be made.

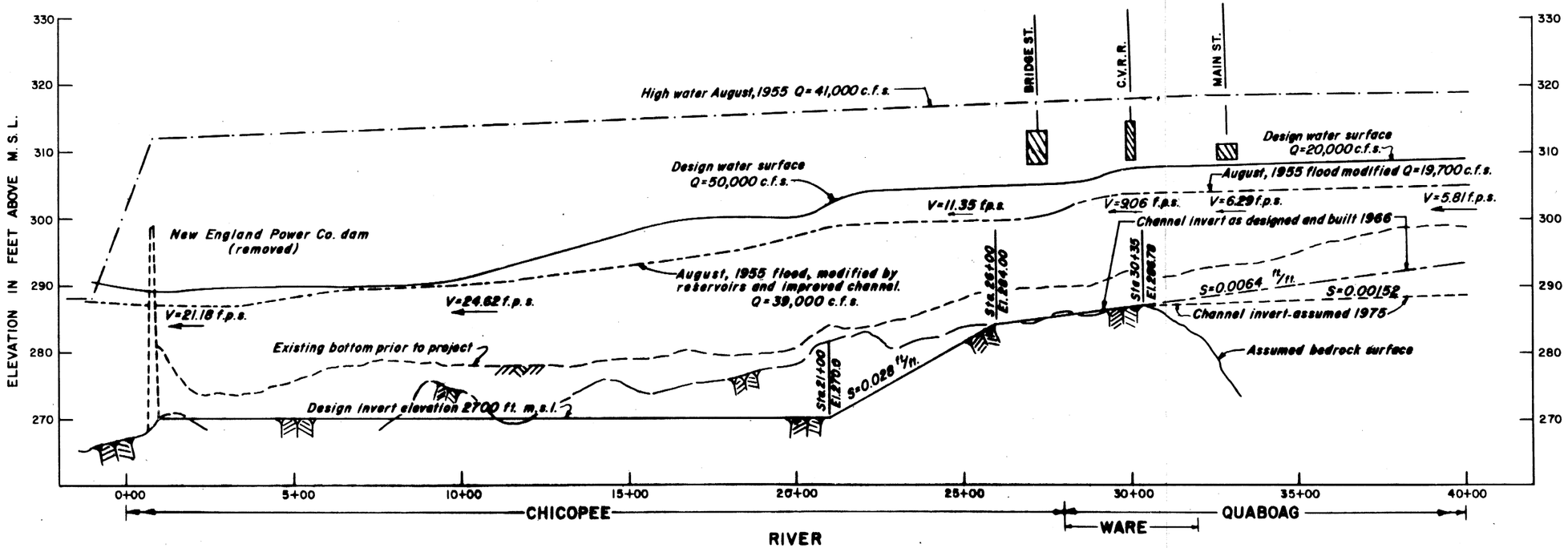
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

CONNECTICUT RIVER FLOOD CONTROL
THREE RIVERS
GENERAL PLAN AND INDEX
CHICOPEE RIVER — MASSACHUSETTS

DATE: APRIL 1963

CT-5886
SHEET 1

PLATE 1


ELEVATION IN FEET ABOVE M. S. L.
330
320
310
300
290
280
270
High water August, 1955 Q=41,000 c.f.s.
BRIDGE ST.
C.V.R.R.
MAIN ST.
Design water surface Q=20,000 c.f.s.
Design water surface Q=50,000 c.f.s.
August, 1955 flood modified Q=19,700 c.f.s.
V=11.35 f.p.s.
V=9.06 f.p.s.
V=6.29 f.p.s.
V=5.81 f.p.s.
New England Power Co. dam (removed)
Channel invert as designed and built 1966
August, 1955 flood, modified by reservoirs and improved channel. Q=39,000 c.f.s.
Sta. 26+00 El. 284.00
Sta. 30+35 El. 286.79
S=0.0064 ft/ft.
S=0.00152
V=24.62 f.p.s.
V=21.18 f.p.s.
Channel invert-assumed 1975
Existing bottom prior to project
Assumed bedrock surface
Sta. 21+00 El. 279.0
S=0.028 ft/ft.
Design invert elevation 270.0 ft. m.s.l.
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
40+00
CHICOPEE
QUABOAG
WARE
RIVER

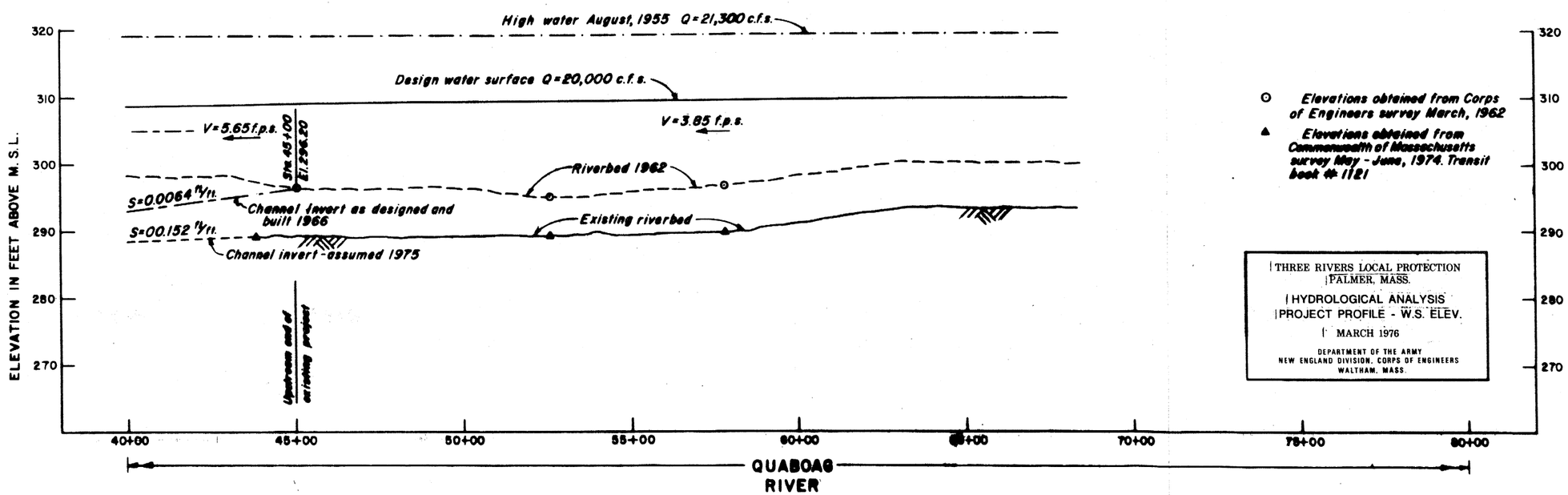
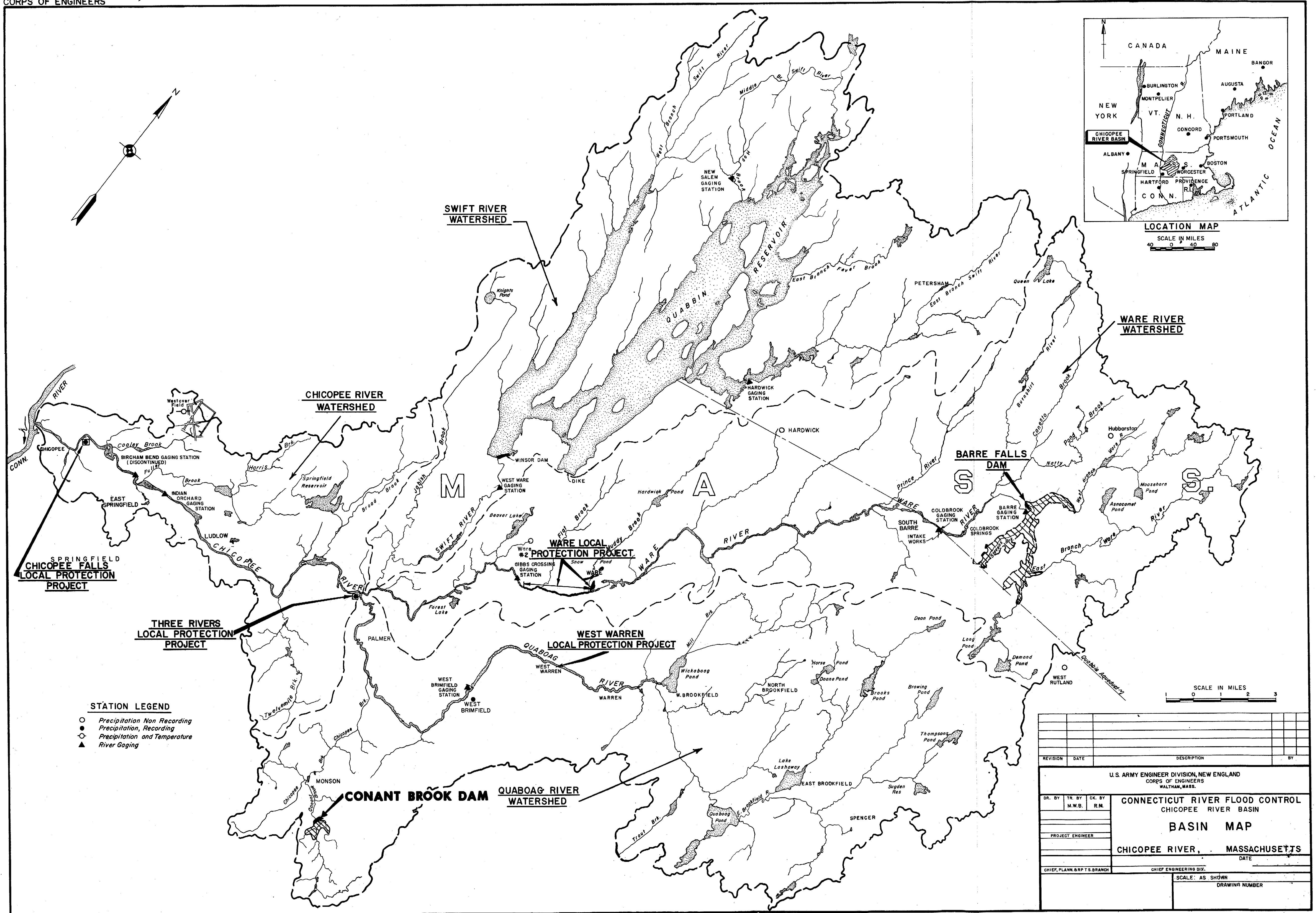
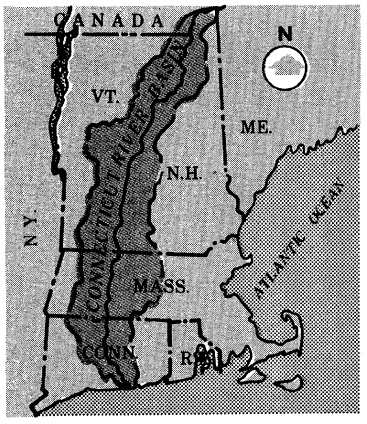

ELEVATION IN FEET ABOVE M. S. L.
320
310
300
290
280
270
High water August, 1955 Q=21,300 c.f.s.
Design water surface Q=20,000 c.f.s.
V=5.65 f.p.s.
V=3.85 f.p.s.
Sta. 45+00 El. 296.20
Riverbed 1962
S=0.0064 ft/ft.
Channel invert as designed and built 1966
Existing riverbed
S=00.152 ft/ft.
Channel invert-assumed 1975
Upstream end of existing project
40+00
45+00
50+00
55+00
60+00
65+00
70+00
75+00
80+00
QUABOAG
RIVER
Elevations obtained from Corps of Engineers survey March, 1962
Elevations obtained from Commonwealth of Massachusetts survey May - June, 1974. Transit book 4: 1121
THREE RIVERS LOCAL PROTECTION
PALMER, MASS.
HYDROLOGICAL ANALYSIS
PROJECT PROFILE - W.S. ELEV.
MARCH 1976
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 2


SWIFT RIVER WATERSHED
CHICOPEE RIVER WATERSHED
WARE RIVER WATERSHED
QUABOAG RIVER WATERSHED
QUABBIN RESERVOIR
BARRE FALLS DAM
WARE LOCAL #2 PROTECTION PROJECT
CHICOPEE FALLS LOCAL PROTECTION PROJECT
THREE RIVERS LOCAL PROTECTION PROJECT
WEST WARREN LOCAL PROTECTION PROJECT
CONANT BROOK DAM
M
A
S
S.
SPRINGFIELD
CHICOPEE
EAST SPRINGFIELD
LUDLOW
PALMER
MONSON
WARE
HARDWICK
PETERSHAM
SOUTH BARRE
WEST WARREN
WARREN
W. BROOKFIELD
NORTH BROOKFIELD
EAST BROOKFIELD
SPENCER
WEST BRIMFIELD
WEST RUTLAND
Hubbardston
WINSOR DAM
DIKE
Westover Field
BIRCHAM BEND GAGING STATION (DISCONTINUED)
INDIAN ORCHARD GAGING STATION
WEST WARE GAGING STATION
GIBBS CROSSING GAGING STATION
NEW SALEM GAGING STATION
HARDWICK GAGING STATION
COLDBROOK GAGING STATION
COLDBROOK SPRINGS
INTAKE WORKS
BARRE GAGING STATION
WEST BRIMFIELD GAGING STATION
Quabbin Aqueduct
CONN. RIVER
CHICOPEE RIVER
SWIFT RIVER
WARE RIVER
QUABOAG RIVER
Prince River
Springfield Reservoir
Beaver Lake
Forest Lake
Knights Pond
Queen Lake
Wickaboag Pond
Lake Lashaway
Quaboag Pond
Long Pond
Demond Pond
Dean Pond
Brooks Pond
Browning Pond
Thompsons Pond
Sugden Res
Asnacomet Pond
Moosehorn Pond
STATION LEGEND
Precipitation Non Recording
Precipitation, Recording
Precipitation and Temperature
River Gaging
SCALE IN MILES
1 0 1 2 3
LOCATION MAP
CANADA
MAINE
NEW YORK
VT.
N. H.
MASS.
CONN.
R.I.
ATLANTIC OCEAN
CONNECTICUT R.
CHICOPEE RIVER BASIN
BANGOR
AUGUSTA
PORTLAND
BURLINGTON
MONTPELIER
CONCORD
PORTSMOUTH
ALBANY
BOSTON
WORCESTER
SPRINGFIELD
HARTFORD
PROVIDENCE
SCALE IN MILES
40 0 40 80
REVISION
DATE
DESCRIPTION
BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
DR. BY
TR. BY M.W.B.
CK. BY R.M.
CONNECTICUT RIVER FLOOD CONTROL
CHICOPEE RIVER BASIN
BASIN MAP
CHICOPEE RIVER, MASSACHUSETTS
PROJECT ENGINEER
DATE
CHIEF, PLANN. & RP'TS. BRANCH
CHIEF ENGINEERING DIV.
SCALE: AS SHOWN
DRAWING NUMBER



CANADA

VT.

N

N.H.

MAINE

VT.

N.H.

Upper Ammonoosuc R.

Moose R.

Passumpsic R.

St. Johnsbury

Ammonoosuc R.

Woodsville

CONNECTICUT RIVER

Ompompanoosuc R.

UNION VILLAGE DAM

Willie R.

HARTFORD

Ottauquechee R.

Mascoma R.

NORTH HARTLAND LAKE

Hartland

NORTH SPRINGFIELD LAKE

Black R.

Sugar R.

WESTON

Springfield

CHARLESTOWN

BALL MOUNTAIN LAKE

West R.

SURRY MOUNTAIN LAKE

TOWNSHEND LAKE

VT.

OTTER BROOK LAKE

Brattleboro

KEENE

Ashuelot R.

VT.

MASS.

N.H.

MASS.

Deerfield R.

Greenfield

Millers R.

BIRCH HILL DAM

NORTHAMPTON

Athol

GARDNER

KNIGHTVILLE DAM

TULLY LAKE

LITTLEVILLE LAKE

BARRE FALLS DAM

HUNTINGTON

HOLYOKE AND SPRINGDALE

Ware R.

CHICOPEE

WARE

CHICOPEE FALLS

Omboag R.

WEST SPRINGFIELD AND RIVERDALE

Westfield R.

Chicopee R.

WEST WARREN

THREE RIVERS

MASS.

CONANT BROOK DAM

COLEBROOK RIVER LAKE

CONN.

Farmington R.

SPRINGFIELD

MAD RIVER DAM

WINSTED

SUCKER BROOK DAM

HARTFORD

PARK RIVER (Not Completed)

EAST HARTFORD

New Britain

WETHERSFIELD COVE

HARTFORD TO LONG ISLAND SOUND

EIGHTMILE RIVER

New London

New Haven

ESSEX COVE

NORTH COVE

OLD SAYBROOK

LONG ISLAND SOUND

LEGEND

- RESERVOIRS
- LOCAL PROTECTION PROJECT
- NAVIGATION PROJECTS
- STATE BOUNDARY

NOTE: All projects completed unless otherwise noted

CONNECTICUT RIVER BASIN
New Hampshire, Vermont, Massachusetts & Connecticut

SCALE IN MILES

8 0 8 16 24

PLATE 4

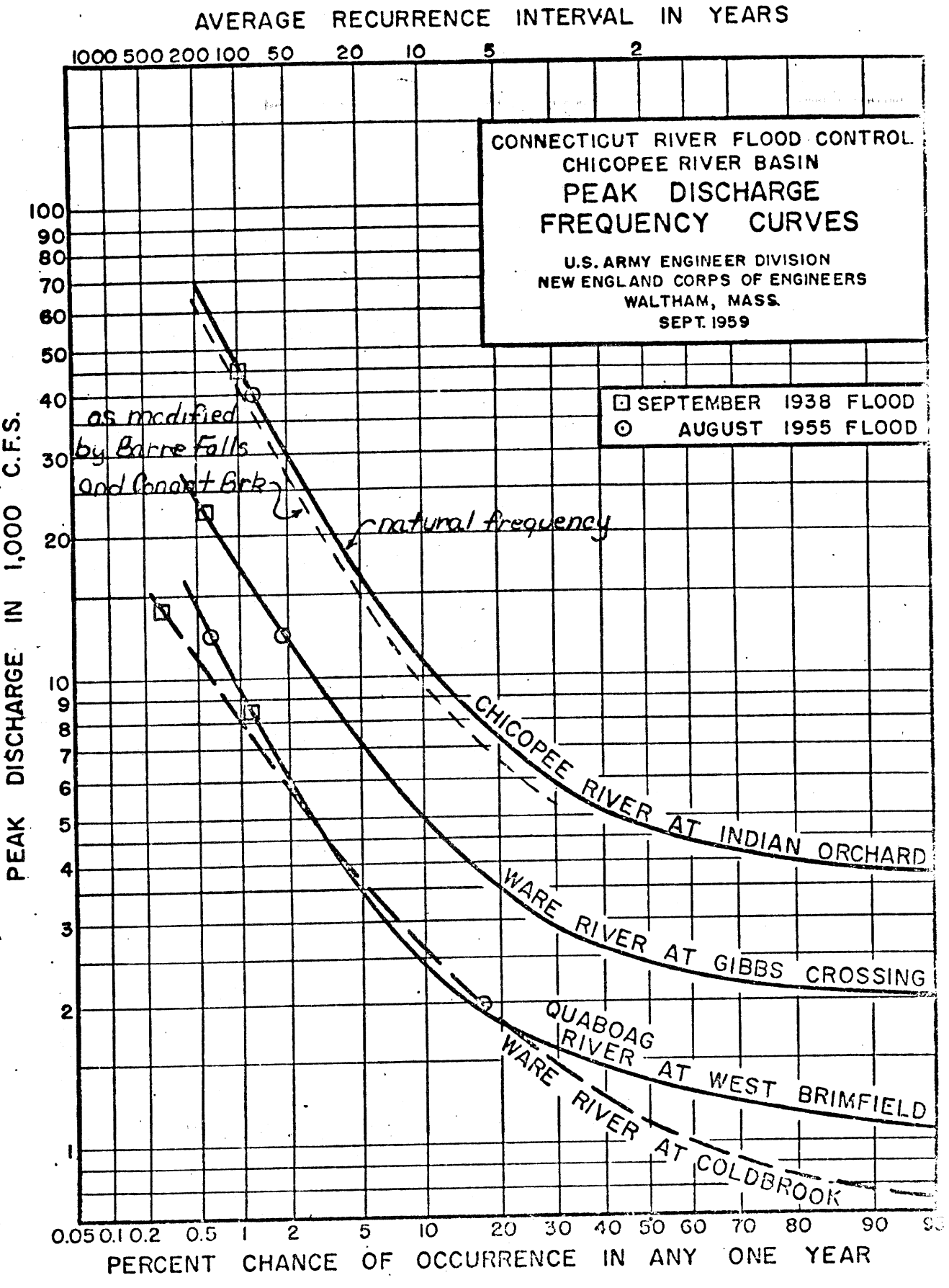
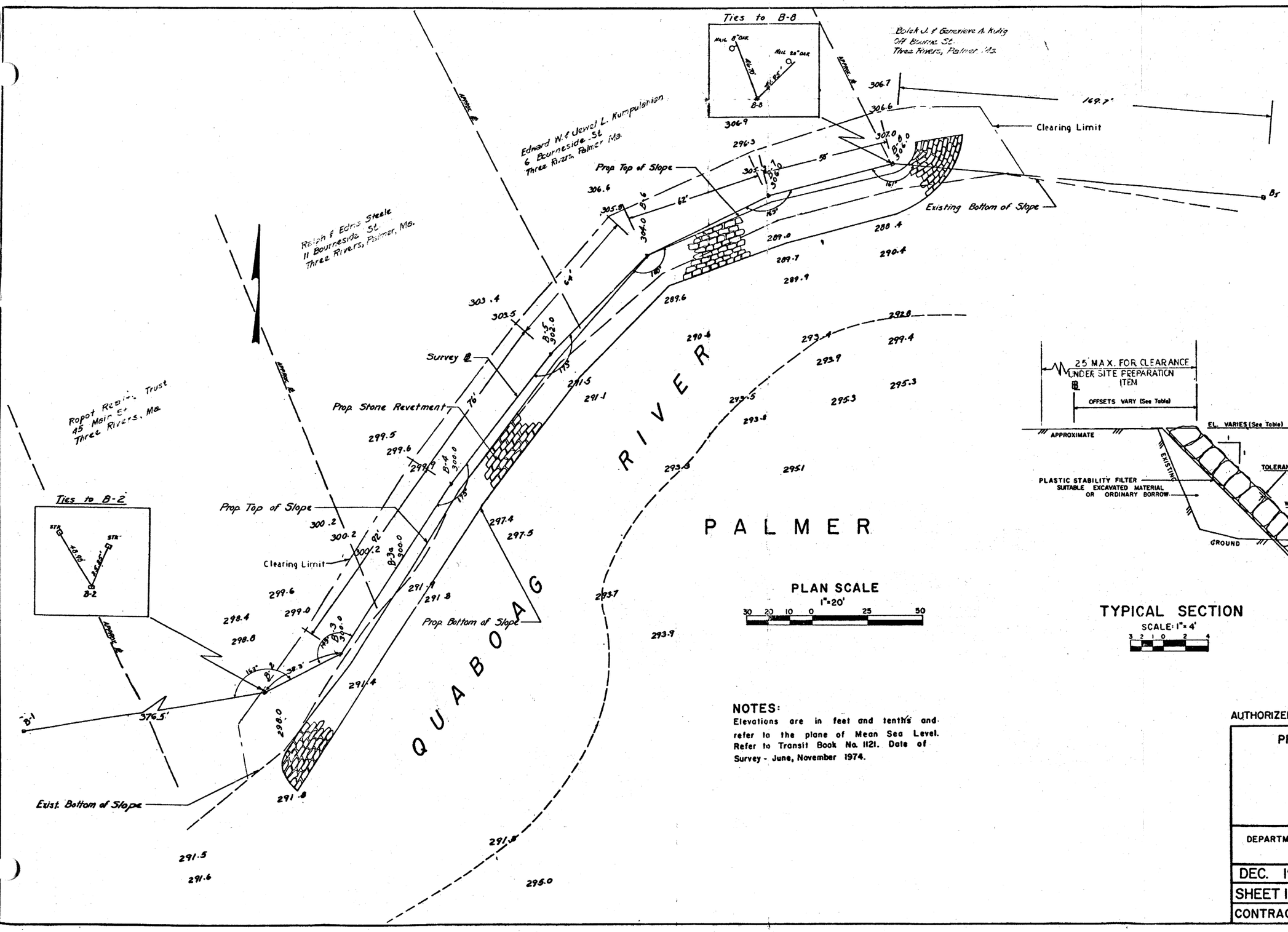

AVERAGE RECURRENCE INTERVAL IN YEARS
1000 500 200 100 50 20 10 5 2
CONNECTICUT RIVER FLOOD CONTROL
CHICOPEE RIVER BASIN
PEAK DISCHARGE
FREQUENCY CURVES
U.S. ARMY ENGINEER DIVISION
NEW ENGLAND CORPS OF ENGINEERS
WALTHAM, MASS.
SEPT. 1959
SEPTEMBER 1938 FLOOD
AUGUST 1955 FLOOD
as modified by Barre Falls and Conant Brk
natural frequency
CHICOPEE RIVER AT INDIAN ORCHARD
WARE RIVER AT GIBBS CROSSING
QUABOAG RIVER AT WEST BRIMFIELD
WARE RIVER AT COLDBROOK
PEAK DISCHARGE IN 1,000 C.F.S.
100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2 1
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90
PERCENT CHANCE OF OCCURRENCE IN ANY ONE YEAR

PLATE 5



OFFSET TABLE

STA.	OFFSET AT SPLIT OF ANGLE	ELEV. @ TOP OF STONE REVETMENT
B-2	28' Rt.	298.0
B-3	6' Rt.	299.0
B-3a	6' Rt.	300.0
B-4	6' Rt.	300.0
B-5	4' Rt.	302.0
B-6	0'.0"	304.0
B-7	3' Rt.	306.0
B-8	4' Rt.	306.0

NOTES:

Elevations are in feet and tenths and refer to the plane of Mean Sea Level. Refer to Transit Book No. 1121. Date of Survey - June, November 1974.

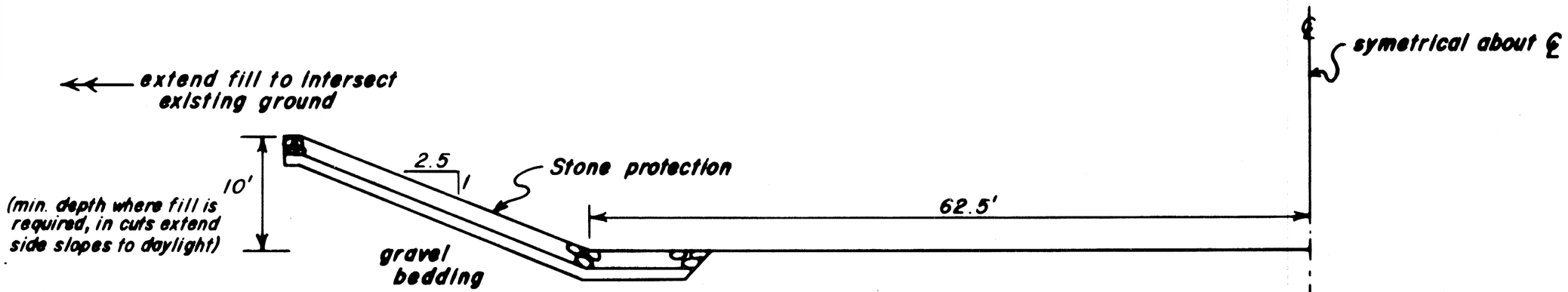
AUTHORIZED UNDER CHAPTER 878 OF THE ACTS OF 1970

PROPOSED EROSION CONTROL
STONE REVETMENT
QUABOAG RIVER
PALMER

DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING
DIVISION OF WATERWAYS

DEC. 1974	DESIGNED BY EBeck	John J. Kenney
SHEET 1 of 1	TRACED BY BMc	CHIEF ENGINEER FOR WATERWAYS
	APPROVED BY EEC	
CONTRACT NO. 2815	ACC. NO. 05030	

PLATE 6



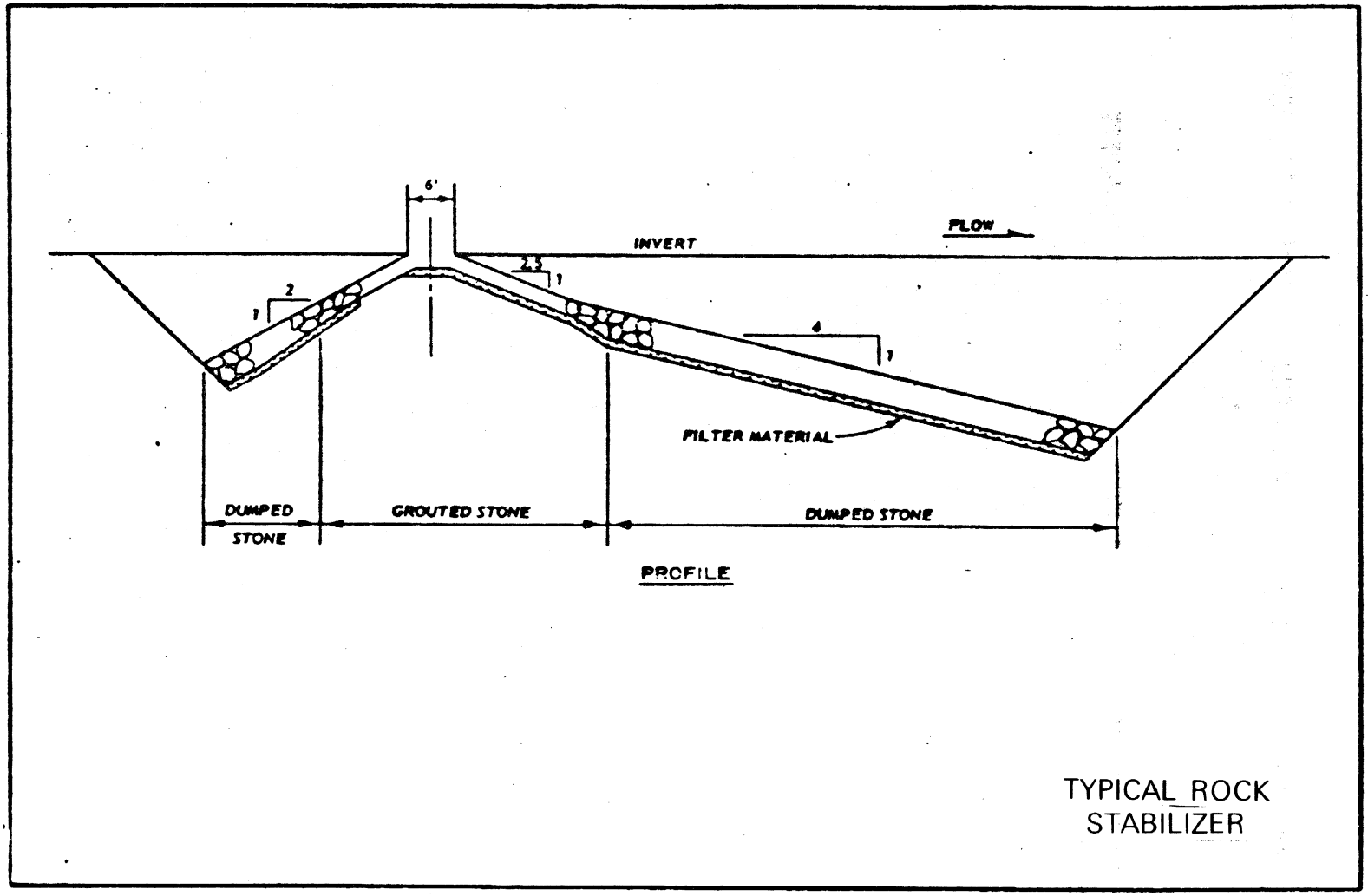
SUGGESTED DESIGN FOR LOW FLOW CHANNEL
Sta. 39+00 to 68+24 QUABOAG RIVER

Scale: Hor: 1" = 10'
Ver: 1" = 10'

THREE RIVERS LOCAL PROTECTION
PALMER, MASS.
HYDROLOGIC REVIEW
UPSTREAM PROPOSED CHANNEL IMPROVEMENT
QUABOAG RIVER
MARCH 1976

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 7



TYPICAL ROCK STABILIZER

PLATE 8

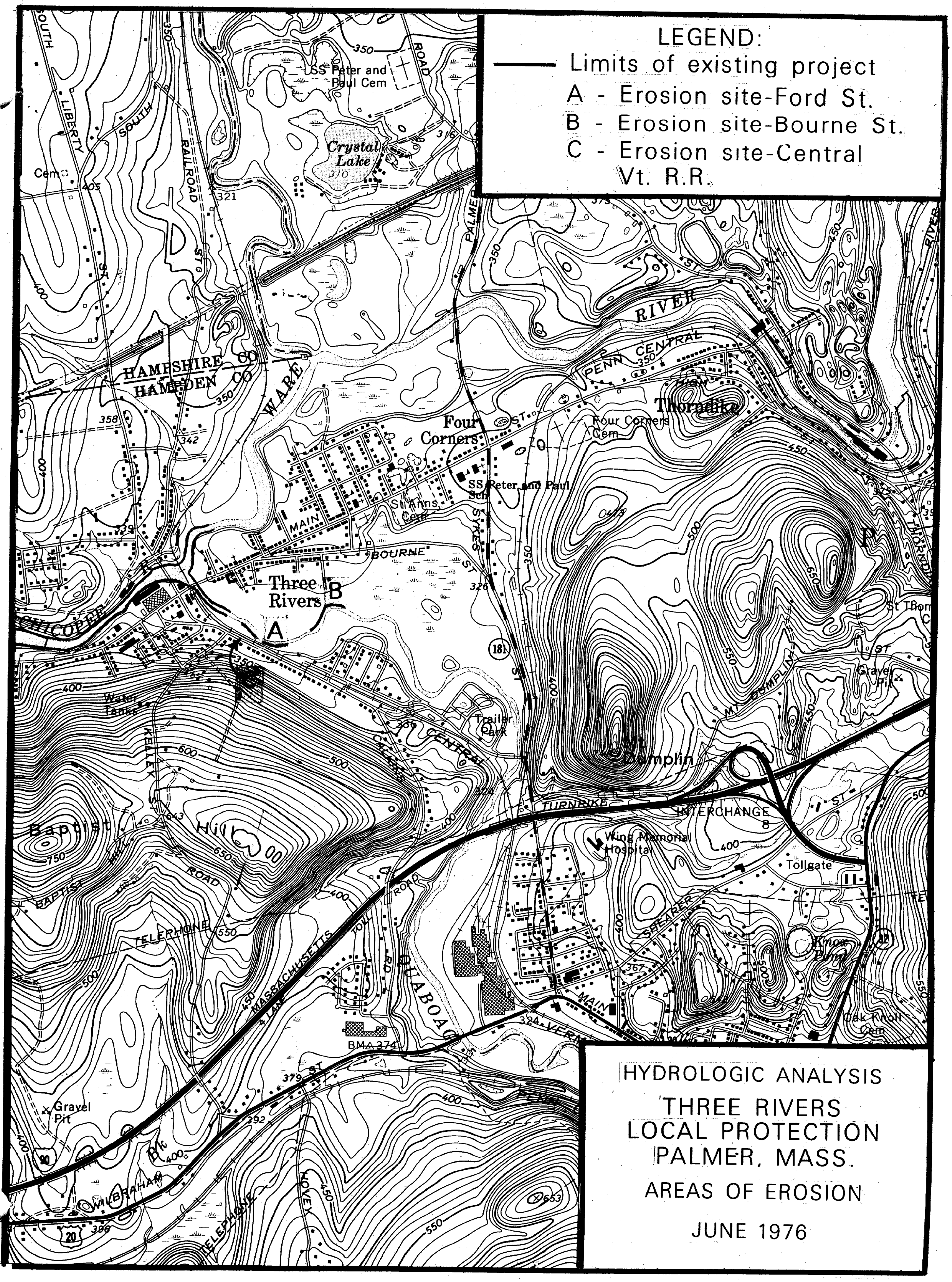

LEGEND:
Limits of existing project
A - Erosion site-Ford St.
B - Erosion site-Bourne St.
C - Erosion site-Central Vt. R.R.
HYDROLOGIC ANALYSIS
THREE RIVERS
LOCAL PROTECTION
PALMER, MASS.
AREAS OF EROSION
JUNE 1976
SS Peter and Paul Cem
Crystal Lake
WARE RIVER
HAMPSHIRE CO
HAMPDEN CO
CHICOPEE
Four Corners
Four Corners Cem
Thorndike
SS Peter and Paul Sch
St Anns Cem
BOURNE
Three Rivers
A
B
C
Water Tanks
Trailer Park
Mt Dumplin
TURNPIKE
INTERCHANGE 8
Wing Memorial Hospital
Tollgate
Baptist Hill
TELEPHONE
MASSACHUSETTS
QUABOAG
Gravel Pit
WILBRAHAM
Oak Knoll Cem

PLATE 9